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Canadian Society of Civil Engineers.

INCORPORATED 1887.

TRANSACTIONS.

MASONRY WORK OF THE CHEAT RIVER BRIDGE.

By Cecil B. Smith, A.M.Can.Soc.C.E.

To be read Thursday, Jan. 4th, 1894.

This bridge, built during 1892-93, by the Baltimore & Ohio R.R.Co., at its crossing of this river, on the State Line R.R., between Uniontown, Pa., and Morgantown, W. Va., was, with other work, put in charge of the author of this paper in July, 1892.

Amongst the first duties were to establish, accurately, the highest known flood level, and also to make surveys and soundings of Cheat River for $2\frac{1}{2}$ miles above the proposed bridge site, this latter information being needed to demonstrate to the Federal Government that this river was unfit for navigation and its improvement impracticable, in order that the grade of our crossing might be placed, as near as safety might warrant, to the flood level.

The highest known water was in July, 1888, when the river rose exactly 30 feet, above pool level, at this point.

It will be understood that the Cheat River empties into the Monongahela immediately below the bridge, and that this latter river is improved for navigation from Pittsburg, Pa., to Morgantown, W. Va., by a series of dams and locks, which pool the water about every 10 miles, on an average.

Pool No. 9, of Monongahela, backs 2 miles up Cheat River, at low water, and has raised the water level at the bridge site 8 feet, or from an original depth of 5 feet to a present one of 13 feet at low water.

The grade line was put 35′ 6″ above pool, and bridge seats 32′ above pool, or only 2 feet above the highest known flood level.

This seems very little margin, but when it is considered that only exceptional floods raise over 15 or 20 feet, and that any higher water than 30 feet would allow the water to flow over a large area, through the village of Point Marion, and thence to the Monongahela by another channel, it will appear quite sufficient, especially as the drainage area for 150 miles and including all its branches is in a mountainous region where the conditions are not likely to be ever changed, by clearing the land, to any great extent, for cultivation.

The Bridge consists of 4 through spans 135′ centres, and 2 half through plate girders of 85′ and 65′ over all, or a total length of 690 feet, and is now being put in by the Pencoyd Bridge Works.

It will be noticed, by the general plan, that 200 feet of the bridge is on a 9° 45′ curve. This is arranged for by lengthening Piers I and II (Plate XIII) sufficiently to space the main trusses of these spans enough wider than those on tangent to allow for curvature.

This is not as bad a feature as it otherwise would be, owing to the proximity of a depot and town, thereby causing trains to slow down at the bridge.

The triangulations were carried out in duplicate and checked to $\frac{1}{10}$ foot; the average was taken, and found afterward, by actual measurement, to be within $\frac{1}{20}$ foot of being correct.

The main base line was laid out exactly parallel to the axes of the piers, and both base lines were hubbed and levelled every 50 feet. The

levelling was found necessary, even on fairly level ground, as a 400 ft. base line shews $\frac{1}{20}$ foot error when tape was levelled by the eye only, over fairly level ground.

The angles were repeated 12 times with a young transit graduated to minutes only, and checked to within $\frac{1}{4}$ minute on averages.

This error of closure was found to be always on the small side. One writer ascribes this fact to the instrument being out of level by repeated turnings, but the author believes it to be due to a slight dragging of the axis in the direction turned.

The soundings were taken by a very simple method: The positions on the base line *exactly* at right angles to each sounding needed were fixed on the ground, as also on a similar base line on the other side of the river also parallel to the axes of the piers. This gave one range, operated entirely by rodmen or axemen. The other range was by transit angles from the distant end of a base line.

In fixing the dredge flags, afterwards, the same method was adopted and found to work very well. This, in case one transitman only is available, and for rivers not over 500 or 600 ft. wide, will be found a ready method albeit probably familiar to most of my readers.

The soundings for pier foundations disclosed a thin layer of closely cemented gravel, overlying soft clay shale at Piers II, III and IV.

13 feet of mud and gravel overlying rock at Pier V.

And apparently solid rock within 7 feet of water surface at Pier I.

This last information was afterwards proven entirely incorrect, and came near causing great trouble.

The seeming solid rock, obtained in about 15 different readings, which all made the rod ring, was merely a solid mass of huge boulders forming the toe of an *ancient* slip, from the mountain side adjacent, and which extended from about 200 feet above the water to the bottom of the river, and varied from 3 to 20 feet in thickness.

When the cofferdam, made by an artificially made filling, above water level, into which sheet piles were hand driven, encountered these boulders, driving had to be discontinued, and another row of sheeting and ring of timbers put in. This was, with much difficulty, carried down completely past the slipped material to a firm clay foundation, nearly level with the river piers foundations.

The masonry base was well spread out, and the pier has not settled by the slighest noticeable amount, when tested by levels.

The foundation for the north abutment was commenced before that of Pier I, the material being wheeled to form the artificial dam mentioned; and as it was supposed that solid rock was within 7 feet of water level, or 16 feet of ground surface, or even less, no great difficulties were looked for. It was accordingly thought ample to lay out foundation pit 4 feet all around larger than the proposed pilaster, which was to be 12′ 6″ at its greatest width.

Here would seem a good opportunity to warn beginners in foundation work of any great possible depth: "Be sure to lay them out "amply large for supposed needs, and then add 1 or 2 feet all around "for exigencies."

After this foundation was carried down 12 feet, the old slip, before mentioned, consisting of clay and boulders, was encountered, and it became evident that the pit must be carried down past this layer to a firm clay at least.

A second row of sheeting was necessary, and the question at once arose:—

Whether the abutment, as originally designed, was heavy enough to withstand the pressure of a mountain side behind, liable to move at any moment, and with only a narrow support (See Plate X for cross-section) between the abutment and the river!

It was resolved to carry down as large a foundation pit as possible and fill it with masonry. Soft rock was obtained 23 feet below ground and neat lines, or about 49 feet below grade, and a width of 14 feet there given to the masonry and concrete. This width was carried up to

the neat work, and all spaces between the masonry and sheeting carefully rammed with concrete or earth; the remainder of the abutment was built according to plan.

During the excavation of this foundation the pressure on the timbering was enormous. The 12″ x 12″ struts were spaced 6 feet apart longitudinally, and the rings were about the same distance apart vertically; but these were found, in places, to be crushing the timber rings to such an extent as to require many extra ones. There is no doubt but that the building of a spur from the main line at this point, along with the embankment for the main line itself, had put the mountain side out of balance, and the whole mass was pressing on the back of the excavation timbering.

This point is made clear by two facts, which were discovered during the progress of the work: 1st, a bench mark on a very large sound stump 200 feet up the river from the abutment had settled 22-100 foot before being discovered (luckily causing little or no errors); and 2nd, that a deep well about 500 feet down the river from the abutment was 2 or 3 feet out of plumb, although only dug for 2 or 3 years.

The whole country, along the banks of this river and the Monongahela, is in a state of unrest, and needs hardly any provocation to make it move slowly but surely toward the river's edge.

On bringing the embankment forward after the abutment was completed, a slight crack appeared in the flared back wing, but on ceasing to add new material when almost completed, the crack ceased to enlarge, and the abutment is since standing all right. By adding a few cars of coke cinders the load will not be appreciably increased and the embankment completed.

This abutment was thoroughly well built of the very best description of first class masonry facing, with heavy well bonded coursed rubble backing, the average size of stones being about 2½′ x 5′ x 2′.

The work was done under the closest inspection, very few spalls were used, and an abundance of mortar where needed.

By the cross section on Plate X, it will be seen that it was designed for 4-10 height plus front batter, to the ground line, and a pilaster below. On the same plate are cross-sections of a few other abutments built at the same time under supervision of the writer, of good second class masonry throughout (which by B and O specification is almost as good as first class masonry in this region of large sized stones) in which the same rule has been substantially followed.

All of these abutments were subjected to unusually severe conditions; all were loaded with wet, heavy material behind, and had weak supports for their pilasters in front, most of them were partly built in the winter season, and all were loaded soon after completion with a running grade, dump, and entirely untamped. Yet they have stood to their work with slight cracks, which ceased in a few days after the severest strains were over.

Theory has wrestled more or less successfully with the design of earthwork retaining walls, and as it has not positively determined any one of the three conditions necessary to a successful solution of the question, namely, the amount of thrust, its direction, and point of application, it is most interesting to know, not so much, that an abutment has stood the test of time, but that it is, as nearly as possible, the most economical structure for fulfilling a given duty.

Someone has said that: "Those are poorly designed culverts on a "line of railway in which not even an occasional one at widely separated "intervals has failed to carry the rainfall." And in the same way, although not arguing to the point of failure, those are poorly designed abutments that are so needlessly strong as to be far above their requirements at the moment of greatest strain, which moment is when the cement is not fully hardened and the embankment settling rapidly and full of moisture.

Never again will such a structure be called upon for so great a load, as in the first few days or weeks after the embankment has been built.

Once it has stood this ordeal we may consider it safe from all damage except by weathering and frost.

The author has also placed on Plate X the section of an abutment built in Canada, in 1888, under his supervision, which is of much heavier design, and as it had very good opportunity to get fully set before the embankment was made in layers by train, it would seem very heavy for its duties, unless the greater severity of climate of Ontario over that of Pennsylvania, which is very small in amount, be counted against it.

The author would very much desire opinions from members of the Society, engaged in such work, on this much vexed question.

Plate XI shows some details in constructing the river piers.

The dredging lines were marked by 4 flags for each excavation, 2 in the line of each side of a pit, one being 20 feet distant from the up stream end of the pit to measure from, the other some 200 feet further up stream to give line.

These flags were very large quarry stones, with a 20 foot scantling dowelled on to one side in an upright position, a rope attached to the stone and slipped over the top of the flag served to raise the stone for removal or setting. The dredges were worked backward down stream, and did not interfere with the flags.

The pits were dredged 5 feet all around larger than the timber cribs, to allow for variation in sinking the latter, this being sufficient, as the dredging was only about 1 to 2 feet deep, and chiefly consisted of gravel and soft shale. After dredging a pit to a fairly even surface, the dredge was drawn up alongside and anchored (with spuds).

The side was then graduated every 3 feet, and a small coal barge, placed at right angles, done in the same way.

Soundings were then taken every 3 feet each way, and after being recorded on a diagram (See Plate XI.) the high spots were found by inspection. A diver was then sent down to these spots, which he levelled off by hand or with a bar; by this means a good surface for the foundation of the cribs was obtained, but further uniformity was secured by a thin layer of broken stone carefully shovelled from a barge into the low places, by aid of sounding poles, with large iron shoes, to prevent their entrance into the smallest interstices.

The timber cribs, with caissons properly attached and caulked, were then floated into place, and after being roughly located were anchored by guy lines attached to shore or to sunken boxes of stone, which were used because ordinary anchors were not on hand, and would probably have dragged on the rock bottom if they had been.

Masonry was then built into them until bottom was nearly reached, when they were carefully located by transit and wires from the shore, and sunk.

The wire used was No. 15 German Piano wire, stretched to about 30 lbs. tension, tagged every 5 feet, where needed, with pieces of wire, attached by solder. To make the solder firm it was found necessary to remove the exterior coating of the wire by muriatic acid.

During the sinking of one of the cribs, the foreman, with it within 2 or 3 feet of bottom, found one corner high, and, before getting carefully located, thought it better to get the crib levelled up, after which the practice was to put the crib in exact position, about 1 foot above bottom, and then by piling on large stones at one end that end was lodged and the position fixed. But alas! for him, in this case, being *out* of position, it had lodged on a high undredged corner; and after putting 10 or 15 of the largest stones he could find on this obdurate corner, it was still high, and the theory of hydraulics put to confusion. On discovering the true state of affairs, he, painfully but wrathfully, removed the stones in order to move his crib at all, all of which has a moral attached.

Of course a crib cannot be landed perfectly exact in position, but all that is necessary is to get it so nearly so that the neat work,

when laid out, will have a good footing all around, on the pilaster. For this purpose the latter was designed 14 all around larger than the neat work.

The noses of the pilasters were brought into shape gradually in the top 3 courses, so as to give good bond with the neat work.

Rip rap was placed around the piers after completion, as shewn on Plate XI, consisting of 1 and 2 man stones, taking a natural slope, and also of smaller stones placed carefully between the caisson and masonry during the sinking of the crib. All this might have been done without possibly by a poorer corporation, as there is very little current at low water, but under a 5 or 10 foot raise, the current is very swift, and the precaution was considered worth the money ($4,652.50).

The cut waters were plain 45° at one end only, add might possibly have been improved by being put at the downstream end also, to avoid eddy; but this is not appreciable under ordinary water, which is slacked, and the eddy only occurs during raises in the river. These noses are left rock-faced, as it was thought, to look more massive, and to answer the purpose fully as well, as their duties are only to split *soft* ice and divide up jams of logs.

The masonry is all first class, except the backing of the abutments, which is of very heavy superior rubble, and was built under the following general specification of the Baltimore & Ohio R.R. Co.:

"This class of masonry will be ranged rock work of the best de-"scription; the face stones will be accurately squared, jointed and "bedded, and laid in courses not less than 12 inches in thickness, "decreasing from bottom to top of the walls; joints to be well broken, "no break less than 9 inches.

"The stretchers to *average* at least three and a half feet in length, "and none to be less than three feet in length, to have at least sixteen "inches bed for all courses of from 12 in. to 16 in. rise, and for all "thicker courses, at least as much bed as rise.

"The headers to have a width of not less than eighteen inches, and "to hold the size back into the heart of the wall that they shew in its "face. They shall occupy at least one-fifth of the whole face of the wall, "and be, as nearly as practicable, evenly distributed over it, and so "that the headers in each course shall divide equally, or nearly so, the "spaces between the headers in the course directly below. When the "walls do not exceed 3½ feet in thickness, the headers shall run entirely "through, and when they exceed that thickness, there shall be as many "headers of the same size in the rear as in the front of the wall.

"In walls over three and a half feet, and not over six feet in thick-"ness, the front and back headers must alternate and interlock, at "least 12 inches with each other; and in walls over six feet thick, the "headers shall be at least 3½ feet long, and alternate front and back, "as above described, their binding effect being carried through the "wall by intermediate stones, not less in length and size than the "headers of the same course, laid crosswise in the interior of the "work. The stretchers in the rear of the wall and the stones in the "heart of the wall shall be of the same general dimensions and pro-"portions as the face-stones, with equally good bed and bond, but "with less attention to nice vertical joints, and must be well fitted to "their places, and carry the course evenly quite through the wall. "Any *small* interstices that may remain in the heart of the wall will "be carefully filled with small sound stones or chips. The face-stones "shall be left rough on the face, except a square or bevelled draft of "one and a half inches around each stone may be required—no pro-"jection of more than three inches from the draft being, however, "allowed."

To this were added the further requirements that all vertical joints be dressed back true for 12 inches from the face, and that no header should break over a joint, the masonry was all laid in full mortar (except the copings which were grouted), and has drafts, at all vertical angles, 2 inches wide, the only portions of the face that have addi-

tional work are the tops of copings which are fine pointed (but not bush hammered), and the faces of the parapet walls which are rough pointed to facilitate erection of iron work.

The copings were clamped, as shown in plan of abutments, with flat 10″ clamps of $1\frac{1}{2}'' \times \frac{1}{2}''$ section sunk in level and then flushed over with a thick grouting.

The sandstone used was from the coal measures of the carboniferous, and underlies the 9-foot Connellsville coking vein about 100 feet. It is very easily quarried and rifts easy and true to bed, and is so full of quarry sap as to make it very easy cutting. But, on exposure, it hardens rapidly, and in that climate stands weathering well.

The cement used was the Louisville Black Diamond, a very good Rosendale, if used when fresh, but deteriorating rapidly with age. It is of a dark slate color, very uniformly ground, has no free lime to notice, and will stand 45 to 60 lbs. in 24 hours. It was shipped in paper bags, which saves about 20 cts. per bbl., and costs $1.10 per bbl. delivered in Morgantown, W. Va., on cars. Ordinary mortar was mixed 1 cement, 2 sand, and kept continually and thoroughly tempered on the wall until a box was used up. As this is a quick setting cement, this was very necessary, and experiments lately made in Ohio show that cement so tempered does not lose much strength for one or two hours, but if tempered for a long time, say eight hours, will reduce its strength about 80 per cent. at end of one week, and 40 per cent. at the end of seven weeks.

The concrete in abutments was mixed 1 cement, 2 sand, filled with stone, broken for a 2″ ring. The mortar being made as usual, by mixing cement and sand thoroughly before adding water, and then being thoroughly mixed again before adding the stone. This is particularly mentioned, because most contractors (because it is cheaper) and some engineers even make concrete by putting down alternate layers of sand, cement and stone dry, and then add water, and mix by repeated turnings over. This the writer does not consider will blend the sand and cement so thoroughly as in the first method, or give as good results. The concrete was then put down in 9″ layers, and rammed with a 2-man rammer, until water stood on the surface.

In pointing the masonry, all joints were raked out for one inch in depth and pointed thus Stone / Mortar / Stone with mortar mixed 1 sand, 1 cement, which seems in practice to give better results than neat cement mortar, as the latter cracks badly if applied in hot weather.

The timber work was commenced August 29th; masonry work commenced September 24th, 1892; suspended January 10th to March 1st, 1893, owing to river being frozen, and completed April 30th, 1893, or a total of 167 working days, in which time was built :—

367	cubic	yards of	timber,
250	"	"	concrete,
3,710	"	"	masonry.
4,327	"	"	Total,

of which all but the concrete was laid by one gang, or at an average of 25 cubic yards per day, including all stoppages from rain and other incidents.

On one occasion in Pier I, 200 cubic yards were laid in 48 hours, working relays every 12 hours.

The cost of the structure is as follows :—

4,327	c. yds.	Masonry, timber and concrete at	$11.00	$47,597.00
2,085	"	Rip-rap.............................at	2.50	4,652.50
2,085	"	Dry Earth Exc. ....at	.50	1,042.50
179	"	Dry Rock Exc.........................at	1.00	179.00
1,776	"	Wet Exc...............................at	2.00	3,552.00
Superstructure, estimated to cost $33,000..........				33,000.00
Total...				$90,023.00

The contract price given for masonry in the above table included all dredging, coffer-dams, pumping, bailing, timbering, *cement*, sand, and every o er expense connected with the construction of the work, except excavation of foundations, as noted in same table, wet excavation being considered as all material below pool.

There were 1,930 barrels of cement used, out of which about 300 barrels were used in concrete, leaving 1,630 barrels for masonry work proper, allowing 130 barrels as wasted or condemned, which is above the mark, leaves 1,500 barrels for 3,710 cubic yards, or 4-10 barrel per cubic yard.

As this work was watched continually by an inspector, so that no large spaces were allowed, it may be considered a very generous use of cement, especially as the writer has occasion to know that in 5,000 cubic yards of second-class rubble arch and box culvert masonry, built on another part of his work, where the cement was furnished gratis by the company, and also inspected, the average was only $\frac{1}{3}$-barrel per cubic yard.

As the former was a much higher grade of masonry, in which, as before mentioned, very few spaces or interstices of any size were allowed, it reflects creditably on the integrity of the contractors, who were The Drake & Stratton Co. (Ltd.) of Pittsburg.

A GENERAL PLAN OF PIERS.

Plans of abutments and general plan and profile of the bridge are also presented, which may be of some interest as to detail.

They were prepared by Division Engineer, Mr. Andrew Onderdonk, under approval of the Chief Engineer B. & O. R.R. The construction of the State Line & F., M. & P. R.R.'s was under the charge of the former gentleman, and the writer cannot but make mention here of the great amount of new ideas and careful detail that he has learned while with him on these roads and the Roanoke & Southern Railway, of which he was the Chief Engineer.

In conclusion, the author does not claim to have done anything that would be of grea interest to older members of the profession engaged in such works, but hopes that the little incidents and details which go to making up an accomplished piece of work may afford reading matter to those who are just beginning to turn their minds towards such a class of construction.